# Why Should Governments Support Broadband Adoption?

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**ABSTRACT**

Governments justify support of Internet diffusion on two grounds: (1) to overcome a persistent digital divide in broadband availability and (2) to facilitate online activities that are socially or economically desirable. This paper assesses both of these arguments. Using individual-level data from Forrester Research, the analysis finds significantly lower residential broadband adoption in lower-income and lower-density zip codes, controlling for individual characteristics. Further tests show that lower adoption in these areas is evidence of a persistent digital divide in availability. The analysis then assesses how broadband adoption changes individuals' usage of online activities. Broadband adoption increases individuals' frequency of researching health information online, but there is no evidence that broadband adoption increases usage of online job sites or online government services. Localities currently considering municipal wireless (Wi-Fi) initiatives should focus on digital divide justifications rather than expecting to raise usage of a wide range of online activities perceived to be socially desirable.

As of late-2006, numerous localities are in the process of developing wireless broadband networks using Wi-Fi technology that will serve entire cities or regions. Two large cities, Philadelphia and San Francisco, are well into negotiations with vendors, and many others have issued requests for proposals (RFP). City-wide Wi-Fi networks are operational in Anaheim, CA, Annapolis, MD, and many smaller cities and towns.[1] Localities justify these initiatives on two grounds: (1) overcoming the digital divide in availability of broadband and (2) facilitating online activities that are socially desirable or economically productive.

Although these municipal wireless initiatives are recent, the justifications for them are not. Overcoming the digital divide and facilitating certain online activities have helped justify for public involvement in Internet diffusion – not only direct provision but regulation and subsidization as well. The push for municipal wireless is only the latest in a line of public measures to expand Internet access; other examples include the FCC e-Rate program, which gave deep discounts for Internet access to schools and libraries; the USDA's Rural Utilities service, which provided construction loans for broadband infrastructure deployment; and various states' laws requiring telcos to offer "naked DSL," which is high-speed Internet access over a phone line without local telephone service from the same provider. In the past, measures have been aimed at diffusion of computers and of dial-up (slow) Internet access. As dial-up access approaches universal availability, public measures have targeted broadband (fast) Internet access instead.

This paper examines the two justifications for public involvement in broadband diffusion: first, that there remain areas underserved by traditional broadband providers,

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[1] A comprehensive list is available at www.muniwireless.com. For projects mentioned in this paper, current status is given as reported in the June 7, 2006, report, available at www.muniwireless.com/reports/docs/June-7-2006summary.pdf.

and second, that broadband adoption encourages online behaviors that are arguably socially desirable. This study finds that, based on broadband adoption patterns, low-income and low-density zip codes are indeed underserved, in contrast to official FCC measures that suggest that broadband availability is nearly ubiquitous. This study also finds that having broadband, relative to having dial-up, does not generally raise the usage of activities typically considered socially desirable, with the main exception being that broadband subscribers do increase their online research of health information. These findings suggest that the justifications for municipal wireless initiatives and other programs supporting broadband diffusion are somewhat misguided and should instead be justified primarily on digital divide grounds.

## POLICY BACKGROUND

Questions of the digital divide and socially desirable online activities underlie government regulation, subsidization, and provision of Internet services. Municipal wireless initiatives that offer city-wide high-speed wireless Internet access are only the most recent example, but because municipal wireless has involved high-profile debate and support, claims about the digital divide and socially desirable online activities have been made unusually explicit. This section quickly reviews the current state of municipal wireless initiatives.

Municipal involvement in providing Internet infrastructure and services is hardly new. In the late 1990's, a few localities built fiber-optic networks.[2] These earlier projects often involved public ownership of networks and were in direct response to the perceived lack of service provision by the dominant private-sector providers, the phone and cable companies.[3] Most municipal Wi-Fi plans and deployments today call for at least partial ownership and operation by the private sector. As a result, phone and cable companies, after fighting earlier attempts at direct public provision, are instead partnering with local governments to provide wireless networks.[4]

Current controversy over municipal wireless rests on technical issues specific to Wi-Fi: whether Wi-Fi can cover large geographic areas, whether new wireless standard like Wi-Max will soon make Wi-Fi obsolete, and whether a city-wide Wi-Fi signal would interfere with existing Wi-Fi hotspots.[5] There is also controversy on social and economic grounds. San Francisco's plan to have EarthLink provide paid access and to have Google provide free, ad-supported access has raised privacy concerns.[6] And in some cities, the business model for citywide Wi-Fi is under debate, with private-sector partners and localities sometimes disagreeing over whether wireless should be advertising-supported (and free), subscription-based, or a hybrid.[7]

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[2] In Tacoma, WA, the municipal power utility, City Light, built, owns, and operates a fiber-optic network that delivers Internet and television. See "Cities Deliver Broadband for Less," Wired News, March 7, 2003. Available at www.wired.com/news/business/0,1367,57927,00.html.

[3] Gillett, Lehr, Osorio (2003) review many of these local broadband initiatives.

[4] "Companies That Fought Cities on Wi-Fi, Now Rush to Join In," Wall Street Journal, March 20, 2006.

[5] "Wi-Pie in the Sky," The Economist, March 9, 2006, reviews the technological and managerial challenges of citywide Wi-Fi networks.

[6] "Some Worries as San Francisco Goes Wireless," New York Times, April 10, 2006.

[7] EarthLink plans to charge $20 per month in Anaheim and Philadelphia. Google provides free Wi-Fi in Mountain View, CA, and MetroFi offers both free and paid Wi-Fi in Cupertino, Sunnyvale, and Santa Clara, CA. See "S.F. Picks Google Wi-Fi Team," San Francisco Chronicle, April 6, 2006, and "Google Gives City Free Wi-Fi", San Francisco Chronicle, August 16, 2006.

Although the controversies over municipal wireless are specific to Wi-Fi, the justifications for municipal wireless are the enduring claims about the digital divide and socially desirable online behaviors. Localities articulate these themes differently, depending on the demographics of their jurisdictions. Large cities like Philadelphia and San Francisco focus most on the digital divide among residents and the goal of bringing free or low-cost access to everyone. Philadelphia, for instance, negotiated with EarthLink to provide broadband at a lower cost to lower-income residents.[8] The head of San Francisco's director for telecom and information said, "[Municipal Wi-Fi] is really intended to help those people [residents lacking broadband access] first, and everybody else second."[9] Large cities typically want to encourage socially desirable online behaviors around health care, education, and employment.[10] In contrast, the press release announcing Silicon Valley's RFP for a wireless network emphasizes the digital divide among businesses, some of which are out of reach of both DSL and cable providers, and the desirable online activities include those that improve business development, government services, and public safety.[11] Despite these differences, most municipalities' justifications for Wi-Fi cover both closing the digital divide and encouraging certain online activities. The existence of the broadband digital divide and the expectation that broadband access leads to greater usage of socially desirable activities are assertions that

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[8] In contrast, EarthLink will offer service at the same price to all residents in Anaheim. See "Anaheim Striding Toward Wi-Fi Network," Orange County Register, June 30, 2006.

[9] Chris Vein, as quoted in "Some Worries as San Francisco Goes Wireless," New York Times, April 10, 2006.

[10] See, for instance, the literature from Wireless Philadelphia, available at www.phila.gov/wireless/briefing.html; from San Francisco TechConnect, available at http://www.sfgov.org/site/techconnect_tf_index.asp; and from interview with Houston's CIO at http://www.govtech.net/digitalcommunities/story.php?id=98722.

[11] "Public, Private Collaboration To Design Silicon Valley Wide Wireless Network," Joint Venture Silicon Valley press release, January 26, 2006. Silicon Valley, unlike most large cities, has a lower share of low-income residents and more geographically dispersed businesses that aren't well served by DSL or cable providers.

have been largely unquestioned in the debate over municipal wireless; this paper examines both.

## RESEARCH BACKGROUND

Academic economics research has looked at the digital divide both for dial-up and for broadband Internet access, while the research on online behaviors has not focused specifically on broadband.

Economists look at the digital divide in from the supply-side, asking whether the availability of Internet access differs geographically. [12] Evidence suggests that the digital divide has essentially vanished for dial-up Internet access, as it is nearly universally available in the US at low cost.[13] Downes and Greenstein (2002) document that dial-up Internet service spread quickly to even the most rural counties: in 1997 99% of the US population lived in counties with at least one Internet Service Provider (ISP), and 92% lived in counties with seven or more ISP's. Downes and Greenstein (2006) find that the number of ISP's in a county in 1998 was positively correlated with population and with that county located in a metropolitan area. In both papers, Downes and Greenstein define ISP's as offering service in a county if they have a local point-of-presence (POP) – that is, if consumers can dial a local phone number to be connected via modem to the Internet. Having a POP involves scale economies because the cost is spread over the number of users accessing the Internet through the POP, which leads to less provision in remote

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[12] The popular version of the "digital divide" debate refers both to the demand side (whether household characteristics influence adoption) and on the supply side (whether locational characteristics influence availability). Because it is uncontroversial and unsurprising to economists that household characteristics, especially income, influence adoption of broadband and nearly any other consumer product or service, economics research, this paper included, examines the supply-side digital divide.

[13] Dial-up ISP's offer telephone access numbers nearly everywhere, as well as toll-free 800 numbers, effectively making the service universal. Juno, for instance, offers free dial-up service for limited usage (less than 10 hours per month) and unlimited dial-up service for $9.95 per month. See www.juno.com.

areas. Yet, the relatively low cost of dial-up provision resulted in near-universal availability even in the absence of universal service requirements or other subsidies.

There are good reasons to expect broadband availability to follow a different pattern than dial-up availability.[14] Broadband provision involves significant fixed costs of operating switches, lines, and servers. For instance, cable television providers upgrade their networks to be broadband-ready by installing equipment that converts one-way networks suitable for broadcasting television to two-way networks suitable for Internet data transmission. Broadband providers introduce service neighborhood-by-neighborhood, starting in areas where the fixed costs are lowest, demand is highest, or both. Prieger (2003) finds lower provision of broadband in rural areas, though not in lower-income areas, controlling for other demographics. Grubesic (2006) also finds broadband provision lowest in rural and remote areas of the US.

Both Prieger (2003) and Grubesic (2006) rely on Federal Communications Commission (FCC) data on which zip codes broadband providers have subscribers in. However, because broadband may be available in only some parts of a zip code, the FCC's measure overstates the level of broadband availability. Using this measure could also bias any findings about the evenness of broadband availability if providers make broadband available earlier in richer or denser portions of a zip code. Flamm (2006) notes that "the FCC count of high speed line providers within a zip code may seriously misrepresent competitive options available to the totality of residents within that zip code

[14] This paper, as well as research reviewed in this section, considers broadband to include cable and DSL service, which are both wireline-based services. Satellite broadband, unlike cable and DSL, has been almost universally available in the US for many years, but it offers slower speeds and less reliable service for a higher price than cable or DSL. It is not a substitute for cable or DSL in areas where either wireline option is available. See "With a Dish, Broadband Goes Rural," New York Times, November 14, 2006.

… [but] there is no practical alternative to using the FCC data in assessing broadband availability."

A related literature looks at policies that narrow the digital divide by affecting Internet adoption and prices. Clarke et al. (2004) model the response of telecom investment, retail prices, and consumer behavior to regulatory policies and conclude that FCC-proposed rates for leasing access lines from incumbent providers to competitors would lower consumer prices and raise both adoption levels and investment. Wallsten (2005) looks at state-level differences in broadband adoption and regulations and finds universal service regulations and regulated rates for leased lines to have little effect on adoption, while right-of-way guarantees and the presence of competing telecom providers are both associated with higher adoption.

Other research has looked at the impact of Internet adoption and usage in order to identify its benefits, sometimes to address the policy question of public support for the Internet. This literature focuses on search costs, transaction costs, and externalities. Morton, Zettelmeyer, and Risso find that customers using Autobytel.com, a car referral site that provides vehicle price information as well as dealer referrals, pay 2% less than others, and three-quarters of this effect comes from superior information rather than the referral to a lower-cost dealership. In a companion paper (2003) they find that the price premium that racial minorities pay offline for new cars is eliminated when using the Autobytel.com referral service, concluding that the Internet disproportionately benefits those who lack information or are disadvantaged in offline (e.g., in-person) negotiations. Goolsbee and Klenow (2002) find that home computer adoption is greater among people whose family or friends are more likely to use computers and, specifically, email, and they suggest that these externalities could justify subsidization of Internet access.[15] Sandvig (2001) suggests that these externalities can arise unexpectedly: he observes children using the Internet at public libraries primarily for non-"educational" activities like gaming and chat rooms, but points out that the social nature of these applications can encourage children to learn from each other.

Several papers, however, find that the Internet does not necessarily lower consumer prices or even benefit its users. Clay et al. (2002) find that average online book prices are no lower than in traditional bookstores, and online sellers exhibit significant dispersion associated with differentiated strategies. In a study on job search duration, Kuhn and Skuterud (2004) find that job searchers that use the Internet do not have shorter unemployment durations than searchers who do not use the Internet. Furthermore, since the online job searchers have observable characteristics that are more favorable than those of offline searchers, they conclude that either online searchers have unobserved characteristics that are unfavorable or that online search is ineffective.[16]

[15] This externality argument is a natural one for economists to consider but has not been part of the public debate about municipal Wi-Fi.

[16] Kuhn and Skuterud focus on search duration, not ultimate match quality, so they do not assess whether online search could result in better job outcomes that could compensate for the equal or, in some cases, longer search duration of online job searchers.

BROADBAND ADOPTION AND THE DIGITAL DIVIDE

To examine the extent of the digital divide and the impact of broadband adoption on online behaviors, I use proprietary data from Forrester, a technology research and consulting firm. Each year Forrester conducts its Technographics benchmark survey of 60,000-100,000 households about their technology adoption and behaviors.[17]

Forrester's data have several advantages over other microdata on technology adoption and behaviors. Relative to the Current Population Survey (CPS) October computer use supplement files, Forrester's surveys cover a much wider range of technology ownership and online behavior questions. Relative to the Pew Internet and American Life Project, Forrester's data has a much larger sample. Furthermore, some of Forrester's respondents participate in successive years, yielding a two-consecutive-year longitudinal panel of approximately 10,000 US households.

Broadband adoption has grown rapidly but unevenly. In 2000, 2% of households had broadband; six years later, adoption reached 39% (see table 1). Over half of households that have online access from any location have broadband at home. Broadband adoption, however, is much lower in poorer and less urban areas (see table 2). Broadband adoption in the lowest quartile of zip codes, ranked by median household income, is 24%, compared with 55% in the richest quartile of zip codes. In the lowest-density quartile of zip codes, broadband adoption is 24%, rising to 44% in the highest-density quartile.

[17] Forrester's Technographics surveys are conducted by mail; the samples are selected from national market research panels to be representative of US households demographically and are weighted to correct for differences in response rates. Forrester has used TNS/NFO's market research panel since 2001 and used NPD's panel in earlier years. Forrester collects data in the 48 contiguous states and the District of Columbia, but not in Alaska or Hawaii. Brown and Goolsbee (2002), Goolsbee (2000), and Goolsbee and Klenow (2002) use Forrester's data as well.

Higher broadband adoption in richer and more dense zip codes could be the result either of demand-side differences (e.g. higher-income people are more likely to adopt broadband, and higher-income zip codes have more higher-income people) or supply-side differences (e.g., broadband is more widely available in richer and denser zip codes) or both. The Federal Communications Commission (FCC) data, based on surveying providers, suggest that broadband is near-universally available, which implies that these geographic differences in adoption are due to demand-side differences. According to the FCC, in December 2005, broadband was available in 99% of zip codes, accounting for 99.8% of the US population (see tables 3 and 4). Broadband was available in 88% of the most sparsely populated tenth of zip codes, accounting for 96% of the population in those zip codes; broadband was available in 90% of the poorest tenth of zip codes, accounting for 99% of the population in those zip codes. FCC data show that there was a historical digital divide in broadband availability that has closed: in 2000, broadband was available in 73% of all zip codes, but only in 55% of the poorest tenth of zip codes and 28% of the most sparsely populated tenth of zip codes.

However, as argued above, the FCC measure overstates broadband availability and almost certainly understates the unevenness in availability. One point of comparison with the FCC availability data is an online survey Forrester conducted in the fall of 2001, in which 64% of respondents reported that broadband was available where they live, compared to the FCC measure that 98% of the population lived in zip codes with at least one broadband subscriber at the time. The Forrester estimate is probably itself an overestimate because broadband was presumably more widely available in areas where respondents to the online survey lived.

Other ways of measuring broadband availability directly are problematic. Broadband providers do not publish maps showing where service is available because detailed availability maps are considered sensitive competitive information. While customers interested in broadband can check availability at their address on most providers' websites, anecdotal evidence suggests that this information is inaccurate or incomplete.[18]

Rather than rely on FCC data, this paper infers broadband availability by examining the relationship between location and broadband adoption at the individual level, controlling for individual characteristics. The econometric model for assessing the impact of location on adoption is:

$$broadband_i = \alpha + \mathrm{B} locationalchar_j + \Lambda individualchar_i + \varepsilon_i$$

Broadband adoption for person i is a function of characteristics of the zip code j where person i lives as well as individual controls for person i. The location characteristics are zip code log median household income and zip code log population density. The individual controls include household income, household financial assets, respondent age, and respondent education level. B and Λ represent vectors of coefficients on the location characteristics and individual controls, respectively. Additional controls and alternative specifications will be introduced into the model as further tests of the hypothesis that availability varies by location, as described below.

[18] A personal anecdote: over a two-day period in August 2006 of checking the AT&T website and calling several customer service departments to sign up for new DSL service, the author was told by different people that (1) DSL was unavailable at the address, (2) only a slower DSL service (up to 1.5M/s) was available at the address, (3) all speeds of DSL service were available at the address, and (4) the address was not a valid address.

Broadband adoption is higher both in high-density and higher-income areas, controlling for individual characteristics. Table 5 shows that the coefficients on both neighborhood variables are positive and statistically significant. Further, the magnitudes are large, relative to 39% adoption of broadband nationally: doubling zip code income raises broadband adoption by 13 percentage points; doubling zip code density raises broadband adoption by three percentage points. The effect of zip code characteristics on adoption has fallen, relative to the level of adoption, over the period 2004-2006. In 2004, the coefficient on zip code income was .081, relative to a mean in the dependent variable (the level of broadband adoption) of .19, for a percentage change in broadband adoption of 43%; in 2006 the percentage change was 33% (.129 divided by .39). Thus, the relationship between location and adoption is weakening over time as the technology diffuses.

To test whether the relationship between location and adoption should be interpreted as evidence of differences in broadband availability, the same regression is performed using different technologies as the dependent variable. These tests investigate whether the relationship between location and adoption could be due to unobserved individual characteristics that could influence broadband adoption. If, for instance, data on household income and financial assets do not fully measure household buying power, and neighborhood income is correlated with the unmeasured portion of buying power, then the relationship between zip code median income and broadband adoption could reflect demand-side characteristics of households rather than supply-side availability.

The effect of location on adoption of other technologies is different, suggesting that the location characteristics are not picking up an unobserved demand for consumer technologies in general. Table 6 repeats the original specification with cell phone ownership and surround-sound stereo ownership as dependent variables. The coefficient on zip code median income is still statistically significant but only one-third as large for cell phones and for stereos as it is for broadband, relative to the means of the dependent variables. The relationship between zip code population density and these other technologies is insignificant.[19] Finally, with the inclusion of cell phone, stereo, and DVD-player ownership as controls in the broadband regression, the coefficients on zip code characteristics remain essentially unchanged. Thus, the neighborhood characteristics are not picking up an unobserved demand for general consumer technologies.

Looking separately at the two broadband technologies – cable and DSL – further supports the claim that the relationship between location and adoption is due to geographic differences in availability. The previous analysis with cell phones and stereos assessed the impact of location on consumer technologies generally, but there could still be a relationship between location and the demand for broadband specifically.[20] Looking separately at DSL and cable is a further test of the impact of availability on adoption. While DSL and cable are comparable services from the consumer's perspective, technical differences between DS L and cable – as well as strategic differences between telephone companies and cable companies -- imply that different locations would be most profitable for each. The quality of data transmission over DSL disintegrates rapidly with increasing

[19] Location could well have other, specific effects on the demand for cell phone and stereo ownership. One possibility is that density hurts cell phone ownership because high-density neighborhoods may suffer more interference with cell phone reception. The negative relationship between density and surround-sound stereos could arise from the fact that homes in high-density areas are smaller and residents in smaller units have lower demand for powerful stereo systems.

[20] Kolko (2000) shows that, in the early years of commercial Internet adoption, firms in geographically isolated cities were more likely to register domains, controlling for industry, local infrastructure quality, and other factors. Sinai and Waldfogel (2004) show that, for some activities, Internet usage can help overcome various kinds of isolation, but because larger places have more local online content, Internet usage appears to complement metro area size.

distance to the customer from the telephone company central switching offices. DSL is unavailable more than 3 miles from a central office, so DSL availability is greatest in dense downtowns. Yet the ubiquity of telephone service in the US implies that even in very low density areas some houses will be within range of a central office. In contrast, cable companies upgraded networks to broadband first in wealthier suburbs, where the demand for digital cable television (which involves complementary upgrading of equipment) would be highest. But because there is no universal service requirement for cable television, many low density areas lack cable television service, and therefore cable broadband access, altogether.

Differences in adoption patterns of cable and DSL are consistent with availability being a constraint on adoption. Table 7 applies the model to cable and DSL separately. The coefficient on income is much larger for cable (.088) than for DSL (.023) and the difference is significant, consistent with the strategic approach cable companies took in rolling out cable broadband to high-income residential neighborhoods first. The coefficient on density is also larger for cable than for DSL, but the log specification of density masks the important differences. Table 7a uses categorical dummies for zip code density, and the pattern reflects the technical differences between cable and DSL. Cable broadband adoption rises quickly at low density, reaching its peak and staying fairly constant from around 200-6000 people per square mile; in contrast, DSL adoption is constant across density until around 1000 per square mile, with a significant increase starting around 6000 per square mile.[21] These adoption patterns match the availability

[21] To give meaning to these density numbers: 200 people per square mile is typical of small towns and of exclusive outlying suburbs of large cities (e.g. Pound Ridge, NY); 6000 is typical of residential portions of larger cities and their inner suburbs (e.g., Chevy Chase DC/MD, Jamaica Plain MA, and Millbrae CA) and of the downtown neighborhoods of medium-sized cities (e.g., Rochester NY).

patterns one would expect based on technical and strategic differences. Furthermore, these differences in availability are not only the legacy of initial availability differences in the early years of broadband. Table 7b shows that among recent broadband adopters, DSL has a larger share in the lowest-density areas (often unserved by cable) and the highest-density areas (where telephone company central offices are most common), and a smaller share in the middle-density areas, than cable, relative to all broadband adopters.

The above analysis implies that the technological features of broadband and the competitive strategies of broadband providers have resulted in a pattern of adoption consistent with availability being greater in higher-income and higher-density zip codes. The geographic differences in broadband availability are large and appear to be shrinking only slowly. Contrary to the picture of near-universal broadband availability that the FCC measures suggest, this analysis confirms an enduring digital divide in broadband availability.

## BROADBAND AND ONLINE BEHAVIOR

In addition to digital divide arguments, government support for technology diffusion in order to encourage usage of specific online applications. For municipal wireless and other public technology initiatives, governments often expect Internet (or computer) adoption to lead to improvements in health, education, and employment. Furthermore, localities considering municipal wireless hope to encourage usage of online government services. [22] But technology policies don't always have their intended effects. In a study of computer usage among children in San Francisco's public libraries, Sandvig (2001) finds that, rather than using educational or other "productive" applications, as the program intended, kids instead used the machines more for games and chat. This section of the paper looks the effect of broadband adoption on online behaviors to see whether broadband adoption has the effects that policymakers intend.

Broadband users are more likely than dial-up users to do every online activity than dial-up users.[23] Table 8 shows that the differences in doing online activities are especially pronounced for high-bandwidth multimedia activities, such as downloading music. But lower-bandwidth activities, such as visiting job search sites, are also more popular among broadband users than dial-up users. These lower-bandwidth activities benefit from broadband not only from the higher throughput of data that broadband allows; they also benefit from the fact that broadband is an always-on connection and does not require a dedicated phone line. Computer users with broadband who leave their machines always connected eliminate the fixed time cost associated with dialing into a

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[22] Increasing residents' usage of online government services is only one aspect of the broader goal of improved delivery of public services. Many cities have already deployed wireless networks for police and other public employees to use.
[23] This is true for all of the dozens of online activities that Forrester's survey covers, not just the activities discussed in this paper.

slow-modem connection. While the time needed to dial in may only be a matter of seconds, the always-on feature of broadband can make it faster to check movie times online, for instance, than to find them in the paper version of the local newspaper, even if looking in the newspaper had been faster than dialing in over a slow modem.

To overcome the selection effects that could account for cross-sectional differences in online behaviors between broadband and dial-up users, the empirical strategy is to exploit the longitudinal sub-sample of approximately 10,000 respondents to Forrester's surveys from 2005 and 2006. This implicitly controls for person-level fixed effects with change-on-change regressions; additional person-level controls will mitigate remaining selection effects.

The empirical model estimated is as follows:

$$\Delta activity = \alpha + \sum_{x=1}^{4} \beta_x \Delta broadband_x + \delta \Delta income + controls_{2005} + \varepsilon$$

The dependent variable is the change in doing the online activity between 2005 and 2006. Doing the activity at time t is a dummy variable, so the dependent variable takes on the values -1, 0, and 1.[24] The independent variable of interest is the set of dummies covering all possible changes in broadband status:

- broadband in 2006 only ("adopted broadband")
- broadband in 2005 and 2006 ("kept broadband")
- broadband in 2005 only ("dropped broadband")
- broadband in neither 2005 nor 2006 (excluded category)

Using four separate categories, rather than a single variable that equals the change in broadband status, has two advantages. First, this specification allows the effect of having

[24] The dependent variable for amount purchased in the last three months is a continuous dollar value.

broadband in both years to differ from that of lacking broadband in both years; second, this specification estimates the effect of dropping broadband separately from the effect of adopting broadband. These freedoms will allow for a richer interpretation of results.

Although the change-on-change specification differences out person-level fixed effects, controls for basic demographics and online tenure in 2005 are included in case both broadband adoption and doing online activities are correlated with a third factor, such as online tenure. Further, change in income is also included as a control. The specification is conditional on being online in both 2005 and 2006 since the online activity variable is meaningless for people not online in that time period.

Conditional on being online in both periods, 40% had broadband in both years ("kept broadband") and 15% had broadband in 2006 only ("adopted broadband"), as shown in table 9. Three percent dropped broadband. Several reasons could explain why a handful of households dropped broadband: they might have moved to a new location where broadband was unavailable; lowered their valuation of the benefit of broadband after experiencing it; or decided to drop service after an initial low-cost trial period – offered by numerous providers during this time period – ended.

Broadband adopters in 2005-2006 could change their online behaviors differently than past or future broadband adopters. Table 9 shows that, among all households, 24% already had broadband (the "kept broadband") category, so the 2005-2006 adopters were in the third and fourth deciles of the adoption distribution. The 2004-2005 adopters, however, were in the second and third deciles; adopters in 2005-2006 in underserved areas were also in the second and third deciles relative to the populations in their areas. It is possible that one's place in the adoption distribution is correlated with the effect of broadband on online behaviors, and this source of treatment effect heterogeneity will be explored in detail below.

Table 10 shows the basic results for adopters in 2005-2006 with respect to nine online activities: three (music, purchasing, and adult entertainment) that are among the main commercial applications of the Internet for consumers; three (job sites, researching drugs, researching medical conditions) that relate to public policy objectives; and three (government sites, local/city guides, and paying taxes) that could benefit municipalities directly. For each of these, the dependent variable is the change over the period 2005-2006 of doing the online activity at all.

Adopting broadband has a positive and significant effect only on downloading music, purchasing, and visiting adult sites. The impact of adopting broadband raises the likelihood of downloading music by 5.1 percentage points relative to people who lacked broadband in both periods. Relative to the level doing each activity in 2006, the effect of broadband is strongest on downloading music – the coefficient estimate is approximately 33% of the 2006 level (.052 versus .16). Similarly scaled, the coefficient is 9% for purchasing and 24% for visiting adult sites.

For many activities, broadband affects not whether one does the activity at all, but rather the frequency or intensity of doing the activity. Table 11 looks at the same activities but looks at the impact of frequent usage.[25] As before, the impact of adopting broadband is positive and significant for downloading music and purchasing. Also, the

[25] For music, adult sites, job/career sites, government sites, and local/city guides, the "frequent" measure is doing the activity "at least weekly" in 2005 and "a few times a week or more" in 2006; the survey used different frequency categories in 2005 and 2006. For researching drugs and medical conditions, the "frequent" measure is doing the activity at least monthly. For purchasing, the measure is dollars spent online in the past three months. For paying taxes online, frequency doesn't apply since most people's significant tax payments happen one time annually.

impact on researching drugs and researching medical conditions online at least monthly is positive, significant, and large – as large as the effect on downloading music. Yet the impact on frequent usage of other activities – visiting job/career sites, government sites, and local/city guides – remains statistically insignificant.

Moving from the general "visiting government sites" to specific public services: adopting broadband has no impact on residents' use of any specific government service (see table 12). Forrester's surveys ask about ten online government services in 2005 and 2006, such as renewing a driver's license, getting information about public hearings, or ordering consumer publications. The coefficient on adopting broadband for all ten government services is statistically insignificant even at the 10% level.

Looking at the coefficients on "kept broadband" and "dropped broadband" starts to reveal a more nuanced relationship between broadband and online activities. The coefficient on "dropped broadband" for music is negative and significant, and the coefficient on "kept broadband" for music is essentially zero (see table 10). This pattern is consistent with the simple story that broadband causes an immediate and persistent increase in the likelihood of doing an online activity. Drop broadband, and the usage of the activity drops; keep broadband, and the change in doing the activity shouldn't change further.

Other online activities show a more complex relationship with broadband adoption. For instance, the coefficient on "kept broadband" is negative and significant for visiting local/city guides. One possible interpretation is that the impact of adopting broadband isn't simply a same-year jump in doing the activity. Adopting broadband could encourage people to try new online activities, some of which they continue doing and others they discard. Thus, in the second year of having broadband, people might visit certain sites less than in their first year of having broadband, which would be a negative change in the activity relative to the excluded category of people who lack broadband.

A second reason why the impact of broadband on doing online activities could diverge from the immediate-and-persistent-increase pattern is that online activities themselves change over time, possibly in ways that favor either slow or fast Internet connections. If, for instance, online stores adopted technology that improved how the checkout process handles interruptions due to a dropped Internet connection (a scenario rare with broadband but common with dial-up), people who had dial-up in both 2005 and 2006 could have increased their likelihood to purchase relative to people who had broadband in both 2005 and 2006.[26]

There are several potential sources of treatment effect heterogeneity that could make the impact of broadband different for the marginal adopter of municipal Wi-Fi than for the population that adopted broadband in the period 2005-2006. First is that broadband could affect cohorts of adopters differently. Those who adopt broadband in 2005-2006 might change their behaviors differently than earlier or later adopters – either because the people themselves are different or because the online activities have changed. As a result, adopters of municipally provided wireless will start using broadband months or years after the time period this research covers, and later adopters of broadband could change their online behaviors differently than earlier adopters of broadband did. Second

[26] The data do not make it possible to test these different explanations for the significant coefficients on "kept broadband." To test the first explanation – that the impact of broadband might not be immediate and persistent – one would need to follow the same consumer over several years. While a sufficient sample of respondents participates in the Forrester survey for two consecutive years, too few respondents participate for three or more consecutive years to test the longer-term path of effects after adopting broadband. To test the second explanation – that changes in online activities themselves favor dial-up or broadband users – one would need information on consumer behavior or site design that is beyond the scope of Forrester's consumer surveys.

is that people in underserved areas may use broadband for different activities than other people do. For instance, if areas underserved by broadband providers are lacking in retail establishments, the impact of broadband on online shopping could be greater for people in underserved areas. Also, the marginal broadband adopter in an underserved area, where adoption is lower, could have unobserved characteristics typical of an earlier adopter than the marginal broadband adopter in the general population. To assess whether treatment heterogeneity affects the results, the effect of broadband on online activities is compared with the effects for (1) the general population one year earlier and (2) people in underserved areas.

Comparing the most recent broadband adopters with adopters one year earlier shows that the impact of broadband is similar for both groups. Table 13 replicates the analysis above but looks at the changes between 2004 and 2005 rather than changes between 2005 and 2006. For simplicity, only the coefficient on the "adopted broadband" variable is reported. The results are largely consistent: as in 2005-2006, during 2004-2005 broadband adopters were significantly more likely to download music and research drugs and medical conditions.[27] There are some differences: the 2004-2005 broadband adopters were more likely to visit online local/city guides often than non-adopters, yet not significantly more likely to visit adult sites – both in contrast to the 2005-2006 adopters. But the broad conclusions – that broadband adoption increases music downloading and health research online while having little effect on using government services online – apply to this earlier group of broadband adopters.

The impact of broadband is also quite similar for people living in underserved areas, including both low-income zip codes and low-density zip codes. These recent

[27] The effect of broadband on purchasing online is significant at the 10% level.

adopters in underserved areas are a reasonable proxy for those who would adopt broadband in the near future because of municipal Wi-Fi provision. Table 14 shows the results conditional on living in an underserved area. The same empirical framework used in tables 10 and 11 is applied separately to people in low-density and low-income zip codes and compared with the original estimates for the general population. Again, only the coefficient on the "adopted broadband" variable is reported. For nearly all activities, the coefficients for both target groups are in the same direction as for the general population. Because a small sub-sample of the respondents live in underserved areas, standard errors are much higher. Thus, the coefficients on "adopted broadband" for many activities (like purchasing online and downloading music in low-income zip codes, and researching drug information in both low-density and low-income zip codes) are no longer statistically significant but remain of a similar magnitude.

The public policy rationale for municipally provided broadband weakens if, instead of encouraging people to adopt new online activities, it causes people to shift online behaviors from work and other locations to home.[28] To test whether broadband at home displaces at-work online activities, an interaction term indicating broadband access at work in 2005 is added to the basic empirical framework. Since the dependent variable captures whether the respondent is doing the online activity from any location, evidence of displacement would be a positive coefficient on the "adopted broadband" variable and a negative coefficient on the interaction between "adopted broadband" and having broadband at work; that would mean that adopting broadband had less impact on overall online activities among people with broadband at work than among people without.

[28] Employers, of course, would consider it a worthwhile goal to reduce the personal online activities employees do while at work.

For the activities that become more popular among broadband adopters, none exhibits the “work displacement” effect -- that is, the coefficient on the interaction between “adopted broadband” and at-work broadband in 2005 is never negative and significant (see Table 15). Thus, displacement of online activities from work to home is unlikely to be a major consequence of municipal wireless provision for any activity.

DISCUSSION

The main findings are that (1) low-income and low-density zip codes are underserved by broadband and (2) broadband adoption increases only one of the activities – gathering health information – that policymakers hope to encourage. There is no evidence that broadband adoption increases usage of online job sites or online government services

The data do not allow for a convincing assessment of whether causality runs in the opposite direction and the broadband adoption decision is therefore endogenous. One cannot rule out the possibility that individuals get broadband as a result of an increased desire to download music, or research medical information online, or visit adult sites. Endogeneity matters to the policy question: if broadband adoption is endogenous, then the treatment effect of adopting broadband on doing online activities could be reduced or eliminated. However, Forrester's data shows that among new broadband adopters in 2003, the most-cited reasons for getting broadband were increasing the speed for a wide range of general activities, rather than the desire to do specific online activities. Among the online activities explored in this paper, the one most driven by broadband adoption – downloading music – ranks far below general motivations like having an always-on and more reliable connection.[29]

A more rigorous test of endogeneity would be to instrument for broadband adoption using exogenous factors that could drive broadband adoption but have no independent effect on doing online activities. Two instruments for broadband adoption

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[29] In a 2003 survey, only 34% of recent broadband adopters mentioned "faster speed for downloading music or video" as a reason for getting broadband; this reason ranked ninth out of twelve, far below "faster speed for downloading information" (72%), "faster speed for email and communication" (70%), "more reliable connection" (59%).

were investigated. The first was a measure of predicted availability of broadband in the individual's zip code in 2001. In an online survey that year, Forrester asked respondents whether cable or DSL broadband service was available where they lived. Using data on zip code income and density, as well as state dummies, a predicted availability measure was generated for all zip codes in the US. This was hypothesized to be positively correlated with adoption in 2005-2006 for the simple reason that adoption is only possible where broadband is available. The second instrument was whether the respondent moved during 2005-2006. This should be correlated with broadband adoption for two reasons: (1) some people are moving from a location where broadband isn't available to one where it is;[30] (2) people expecting to move might hold off on adopting broadband because broadband often involves fixed set-up costs associated with a specific location.[31] While both instruments were correlated with broadband adoption, they explained little of the variation in adoption and were extremely weak instruments.

An important question that this paper does not address is how the evolution of online offerings and content will change the impact broadband has on online behaviors. Especially relevant to the policy question is whether municipalities, in tandem with facilitating citywide Wi-Fi networks, will expand local government websites and make more government services available online. These research results suggest that making broadband available, by itself, is unlikely to raise the usage of online government services. In fact, if municipalities want to improve public services by having residents

[30] Of course, some people move from a location where broadband is available to one where it isn't. However, conditioning on people who lacked broadband in 2004, 38% of movers during 2004-2005 adopted broadband vs. only 24% of non-movers.

[31] These costs can be both pecuniary and non-pecuniary. Pecuniary costs could include the cost of a modem, access point, or router, as well as the cost of installing new wiring; non-pecuniary costs include the time to set up new service with a customer service rep, either on the phone or in-person.

interact more with the public sector online, it is an open question whether raising the level of broadband adoption is actually a more cost-effective policy than improving government online services through site re-design.

Policymakers might also be thinking too narrowly about the benefits of broadband adoption. While the justification for municipal wireless initiatives point to health, education, and employment, localities should consider online purchasing as a justification for Wi-Fi since the work of Morton, Zettelmeyer, and Silva-Risso (2001 and 2003) suggests that online auto shopping results in lower prices for consumers, especially for consumers who are disadvantaged by the traditional retail process.

Perhaps the most important unanswered question is the effect of broadband adoption on social and economic outcomes, not just on online behaviors. Does making broadband more available to residents improve health outcomes, lower unemployment, or improve job quality? Does making broadband more available to businesses encourage job growth, increase profits, or raise productivity? Does making broadband more available to public officials lower crime rates or improve emergency response? It is a necessary but insufficient condition that for broadband to affect these ultimate social and economic outcomes, broadband must change what residents, businesses, and officials do online. Answers to these questions would help assess how socially or economically desirable various online behaviors are. Answers would also help weigh how important closing the digital divide in availability is versus remedying the unequal access people have to other goods and services.

Table 1: Broadband Adoption in the US

| Year | % of households with broadband at home | % of households online from any location |
|---|---|---|
| 2000 | 2% | 45% |
| 2001 | 7% | 57% |
| 2002 | 10% | 61% |
| 2003 | 15% | 64% |
| 2004 | 18% | 64% |
| 2005 | 28% | 67% |
| 2006 | 39% | 71% |

Source: Forrester

Table 2: Broadband adoption by neighborhood income and neighborhood density, 2006

| | Zip codes ranked by median household income | Zip codes ranked by population density |
|---|---|---|
| Top quartile | 55% | 44% |
| Second quartile | 42% | 48% |
| Third quartile | 34% | 40% |
| Bottom quartile | 24% | 24% |

Source: Forrester and author's calculations

Table 3: FCC measures of broadband availability

| | Percent of zip codes with at least one high-speed subscriber | Percent of **lowest-density** zip codes (bottom decile) with at least one high-speed subscriber | Percent of **lowest-income** zip codes (bottom decile) with at least one high-speed subscriber |
|---|---|---|---|
| December 2000 | 73.2% | 27.5% | 54.9% |
| December 2001 | 79.4% | 43.3% | 62.7% |
| December 2002 | 88.0% | 59.7% | 74.5% |
| December 2003 | 93.2% | 73.5% | 81.9% |
| December 2004 | 95.4% | 74.8% | 83.3% |
| December 2005 | 99.0% | 88.3% | 90.1% |

Source: Federal Communications Commission, High Speed Services for Internet Access: Status as of December 31, 2005, July 2006. Tables 15, 18, and 19. Available at hraunfoss.fcc.gov/edocs_public/attachmatch/DOC-266596A1.pdf.

Table 4: FCC measures of broadband availability

| | Percent of population in zip codes with at least one high-speed subscriber* | Percent of population of **lowest-density** zip codes (bottom decile) in zip codes with at least one high-speed subscriber | Percent of population of **lowest-income** zip codes (bottom-decile) in zip codes with at least one high-speed subscriber |
|---|---|---|---|
| December 2000 | 96.4% | 49.9% | 91.5% |
| December 2001 | 97.8%** | 67.9% | 95.1% |
| December 2002 | 99.1% | 80.9% | 97.5% |
| December 2003 | 99.5% | 88.9% | 98.6% |
| December 2004 | 99.6% | 91.8% | 99.0% |
| December 2005 | 99.8% | 96.2% | 99.4% |

Source: Federal Communications Commission, High Speed Services for Internet Access: Status as of December 31, 2005, July 2006. Tables 18 and 19. Available at hraunfoss.fcc.gov/edocs_public/attachmatch/DOC-266596A1.pdf.

* Based on FCC data and author's own calculation.

** Compared to an online Forrester survey in autumn 2001, in which 64% of online respondents reported broadband availability where they live.

Table 5: Broadband Adoption, 2004-2006

| Dependent variable is broadband adoption in the year: | 2006 | 2005 | 2004 |
|---|---|---|---|
| Log ZIP average income | 0.129* | 0.097* | 0.081* |
| | (0.009) | (0.007) | (0.007) |
| Log ZIP density | 0.031* | 0.025* | 0.020* |
| | (0.002) | (0.001) | (0.001) |
| Fixed effects? | No | No | No |
| N | 57933 | 58357 | 43955 |
| Pseudo R-squared | 0.18 | 0.15 | 0.14 |
| Mean, dependent variable | .39 | .29 | .19 |

- Individual cross-sectional probit regressions; cells show dF/dx evaluated at cell means
- All regressions control for individual age, income, financial assets, education, race, Hispanic origin, household size, and presence of children; clustered on zip codes

Table 6: Adoption of Consumer Technologies, 2006

| Dependent variable: | Have broadband (from table 5) | Own cell phone | Own surround-sound stereo | Have broadband |
|---|---|---|---|---|
| Log ZIP average income | 0.129* | 0.072* | 0.030* | 0.119* |
| | (0.009) | (0.008) | (0.009) | (0.009) |
| Log ZIP density | 0.031* | -0.002 | 0.001 | 0.031* |
| | (0.002) | (0.001) | (0.001) | (0.002) |
| Additional controls? | No | No | No | Own cell phone, DVD player, and stereo |
| N | 57933 | 57933 | 57933 | 57933 |
| Pseudo R-squared | 0.18 | 0.17 | 0.08 | 0.20 |
| Mean, dependent variable | .39 | .79 | .34 | .39 |

- Individual cross-sectional probit regressions; cells show dF/dx evaluated at cell means
- All regressions control for individual age, income, financial assets, education, race, Hispanic origin, household size, and presence of children; clustered on zip codes

Table 7: Cable and DSL Adoption, 2006

| Dependent variable: | 2006 (from Table 5) | 2006: Cable only | 2006: DSL only |
|---|---|---|---|
| Log ZIP average income | 0.129* | 0.088* | 0.023* |
| | (0.009) | (0.007) | (0.007) |
| Log ZIP density | 0.031* | 0.018* | 0.013* |
| | (0.002) | (0.001) | (0.001) |
| N | 57933 | 57933 | 57933 |
| Pseudo R-squared | 0.18 | 0.11 | 0.07 |
| Mean, dependent variable | .39 | .21 | .19 |

- Individual cross-sectional probit regressions; cells show dF/dx evaluated at cell means
- All regressions control for individual age, income, financial assets, education, race, Hispanic origin, household size, and presence of children; clustered on zip codes

Table 7a: Neighborhood Density and Cable and DSL Adoption, 2006

| Dependent variable: | 2006: Cable only | 2006: DSL only |
|---|---|---|
| Zip code density (per sq. mile): | | |
| <25 | Omitted | Omitted |
| 25-49 | .060 (.019) | -.005 (.012) |
| 50-74 | .090 (.020) | -.000 (.013) |
| 75-99 | .112 (.021) | .018 (.014) |
| 100-149 | .166 (.020) | -.009 (.012) |
| 150-199 | .183 (.021) | .005 (.013) |
| 200-249 | .235 (.024) | -.002 (.015) |
| 250-299 | .238 (.024) | .005 (.014) |
| 300-349 | .223 (.024) | .034 (.017) |
| 350-399 | .232 (.027) | -.009 (.017) |
| 400-449 | .262 (.029) | -.009 (.017) |
| 450-499 | .269 (.027) | -.000 (.018) |
| 500-599 | .244 (.025) | .013 (.015) |
| 600-699 | .243 (.026) | .020 (.018) |
| 700-799 | .245 (.027) | .032 (.018) |
| 800-899 | .292 (.031) | .035 (.019) |
| 900-999 | .273 (.029) | .032 (.020) |
| 1000-1499 | .261 (.020) | .028 (.013) |
| 1500-1999 | .258 (.022) | .043 (.014) |
| 2000-2499 | .276 (.023) | .045 (.015) |
| 2500-2999 | .239 (.022) | .047 (.014) |
| 3000-3499 | .248 (.024) | .041 (.016) |
| 3500-3999 | .242 (.025) | .053 (.016) |
| 4000-4499 | .257 (.025) | .057 (.017) |
| 4500-4999 | .240 (.027) | .063 (.019) |
| 5000-5999 | .235 (.023) | .056 (.016) |
| 6000-6999 | .178 (.025) | .091 (.019) |
| 7000-7999 | .148 (.027) | .103 (.023) |
| 8000-8999 | .209 (.034) | .072 (.025) |
| 9000-9999 | .190 (.039) | .140 (.031) |
| 10000+ | .223 (.023) | .090 (.016) |
| N | 57939 | 57939 |
| Pseudo R-squared | 0.11 | 0.07 |
| Mean, dependent variable | .21 | .19 |

- Individual cross-sectional probit regressions; cells show dF/dx evaluated at cell means
- Regressions control for dummies for zip code average income categories
- All regressions control for individual age, income, financial assets, education, race, Hispanic origin, household size, and presence of children; clustered on zip codes

Table 7b: Cable / DSL share by zip code density

| Zip code density (per sq. mile): | Share of broadband households with DSL | Share of broadband households with DSL, online tenure < 2 years |
|---|---|---|
| 0-99 | 61% | 69% |
| 100-499 | 44% | 48% |
| 500-999 | 43% | 40% |
| 1000-4999 | 45% | 53% |
| 5000+ | 53% | 66% |

Table 8: Online activities by connection speed, 2006

| BROADBAND AT HOME? | Yes | No |
|---|---|---|
| **Do each activity ever?** | | |
| Download music | 23% | 9% |
| Visit job or career sites | 24% | 19% |
| Visit government sites | 26% | 19% |
| Visit local or city guides | 38% | 27% |
| Purchase online | 68% | 45% |
| Visit adult entertainment sites | 14% | 8% |
| Research drug information | 45% | 33% |
| Research medical conditions | 59% | 47% |
| File taxes online | 28% | 16% |
| **Do each activity regularly?** | | |
| Download music (few times weekly) | 7% | 2% |
| Visit job or career sites (few times weekly) | 6% | 5% |
| Visit government sites (few times weekly) | 3% | 2% |
| Visit local or city guides (few times weekly) | 5% | 4% |
| Purchase online (dollars, last 3 months) | $252 | $127 |
| Visit adult entertainment sites (few times weekly) | 6% | 3% |
| Research drug information (monthly) | 5% | 4% |
| Research medical conditions (monthly) | 7% | 5% |
| **Do each activity at a government website ever?** | | |
| Download or print gov't form | 29% | 23% |
| Get info about eligibility for benefits | 17% | 15% |
| Get info about public hearing or meeting | 6% | 5% |
| Get information about or apply for gov't job | 10% | 9% |
| Contact public or elected officials | 11% | 9% |
| Order consumer publications | 8% | 7% |
| Apply online for services or benefits | 7% | 6% |
| Renew license or vehicle registration | 23% | 13% |
| Pay a parking ticket | 4% | 2% |
| Get info about real estate or housing | 11% | 8% |

Note: Only households that go online (from any location) are included
Note: All differences are statistically significant at 5% level

Table 9: Summary Statistics for Broadband Adoption

| | 2005-2006 online both periods only | 2005-2006 all households | 2004-2005 all households | 2005-2006, low-density zip codes | 2005-2006, low-income zip codes |
|---|---|---|---|---|---|
| Adopted broadband | 15% | 9% | 8% | 8% | 7% |
| Kept broadband | 40% | 24% | 16% | 15% | 15% |
| Dropped broadband | 3% | 2% | 2% | 2% | 2% |
| Lacked broadband, online both years | 42% | 26% | 32% | 28% | 23% |
| Not online both years | N/A | 39% | 42% | 47% | 53% |

Table 10: Basic results, online activities: EVER do the activity

| Dependent variable is change in: | Download music | Visit job or career sites | Visit government sites | Visit local or city guides | Purchase online | Visit adult entertainment sites | Research drug information | Research medical conditions | File taxes online |
|---|---|---|---|---|---|---|---|---|---|
| Adopted BB | 0.052* | 0.009 | 0.005 | 0.034 | 0.053* | 0.026* | -0.010 | -0.038 | 0.021 |
| | (0.015) | (0.018) | (0.020) | (0.020) | (0.020) | (0.012) | (0.019) | (0.021) | (0.016) |
| Kept BB | 0.002 | -0.003 | -0.047* | -0.026 | -0.027 | 0.008 | -0.023 | -0.003 | 0.019 |
| | (0.011) | (0.013) | (0.015) | (0.016) | (0.015) | (0.009) | (0.015) | (0.016) | (0.012) |
| Dropped BB | -0.081* | -0.045 | -0.089* | -0.070 | -0.017 | -0.002 | 0.019 | -0.076 | -0.067* |
| | (0.028) | (0.033) | (0.038) | (0.039) | (0.038) | (0.022) | (0.037) | (0.039) | (0.030) |
| N | 6056 | 6056 | 6056 | 6056 | 6056 | 6056 | 6056 | 6056 | 6056 |
| R-squared | 0.01 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.01 | 0.01 | 0.01 |
| Mean, dep. var. (2006, all online) | .16 | .22 | .23 | .33 | .57 | .11 | .39 | .53 | .23 |

Notes:

- All regressions control for age, income, online tenure, hours online, and education categories
- Omitted category is broadband in neither 2005 nor 2006

Table 11: Basic results, online activities: do the activity intensively

| Dependent variable is change in: | Download music (weekly) | Visit job or career sites (weekly) | Visit government sites (weekly) | Visit local or city guides (weekly) | Purchase online (dollars, last 3 months) | Visit adult entertainment sites (weekly) | Research drug information (monthly) | Research medical conditions (monthly) |
|---|---|---|---|---|---|---|---|---|
| Adopted BB | 0.026* | 0.019 | -0.009 | 0.010 | 33.938* | 0.006 | 0.030* | 0.032* |
| | (0.009) | (0.012) | (0.009) | (0.011) | (12.909) | (0.008) | (0.009) | (0.011) |
| Kept BB | 0.003 | 0.028* | 0.011 | 0.014 | 11.097 | 0.008 | 0.001 | 0.012 |
| | (0.007) | (0.009) | (0.007) | (0.008) | (9.879) | (0.006) | (0.007) | (0.008) |
| Dropped BB | -0.054* | 0.003 | -0.011 | -0.026 | -20.235 | -0.005 | 0.031 | -0.048* |
| | (0.018) | (0.022) | (0.017) | (0.020) | (24.509) | (0.016) | (0.017) | (0.020) |
| N | 6056 | 6056 | 6056 | 6056 | 6056 | 6056 | 6056 | 6056 |
| R-squared | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| Mean, dep. var. (2006, all online) | .05 | .06 | .03 | .05 | $195 | .04 | .05 | .06 |

Notes:

- All regressions control for age, income, online tenure, hours online, and education categories
- Omitted category is broadband in neither 2005 nor 2006
- NOTE: "Weekly" corresponds in 2005 to "at least one a week" and in 2006 to "a few times per week".

Table 12: Basic results, activities at government websites

| Dependent variable is change in: | Download or print gov't form | Get info about eligibility for benefits | Get info about public hearing or meeting | Get information about or apply for gov't job | Contact public or elected officials | Order consumer publications | Apply online for services or benefits | Renew license or vehicle registration | Pay a parking ticket | Get info about real estate or housing |
|---|---|---|---|---|---|---|---|---|---|---|
| Adopted BB | 0.019 | -0.023 | 0.001 | -0.009 | -0.018 | -0.006 | 0.017 | 0.021 | 0.010 | -0.020 |
| | (0.020) | (0.017) | (0.010) | (0.014) | (0.013) | (0.013) | (0.011) | (0.015) | (0.008) | (0.014) |
| Kept BB | -0.005 | 0.019 | 0.006 | 0.008 | -0.005 | -0.010 | 0.009 | 0.019 | -0.001 | -0.008 |
| | (0.015) | (0.013) | (0.008) | (0.011) | (0.010) | (0.010) | (0.009) | (0.012) | (0.006) | (0.011) |
| Dropped BB | -0.048 | 0.014 | -0.010 | -0.032 | 0.027 | 0.016 | 0.041 | 0.016 | 0.018 | 0.045 |
| | (0.037) | (0.033) | (0.019) | (0.027) | (0.025) | (0.025) | (0.022) | (0.029) | (0.015) | (0.027) |
| N | 6056 | 6056 | 6056 | 6056 | 6056 | 6056 | 6056 | 6056 | 6056 | 6056 |
| R-squared | 0.02 | 0.02 | 0.01 | 0.01 | 0.01 | 0.01 | 0.02 | 0.01 | 0.01 | 0.02 |
| Mean, dep. var. (2006, all online) | .26 | .16 | .06 | .09 | .10 | .08 | .07 | .18 | .03 | .10 |

Notes:

- All regressions control for age, income, online tenure, hours online, and education categories
- Omitted category is broadband in neither 2005 nor 2006

Table 13: Comparison of 2004-2005 and 2005-2006

| Dependent variable is change in:<br><br>Coefficient on **adopted BB** over the period: | Download music | Download music (weekly) | Visit local/city guides | Visit local/city guides (weekly) | Purchase online | Purchase online (dollars, last 3 months) | Visit adult entertainment sites | Research drug information | Research drug information (monthly) | Research medical conditions | Research medical conditions (monthly) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2005-2006 | 0.052* | 0.026* | 0.034 | 0.010 | 0.053* | 33.938* | 0.026* | -0.010 | 0.030* | -0.038 | 0.032* |
| | (0.015) | (0.009) | (0.020) | (0.011) | (0.020) | (12.909) | (0.012) | (0.019) | (0.009) | (0.021) | (0.011) |
| 2004-2005 | 0.052* | 0.027* | 0.058* | 0.029* | 0.041 | 2.882 | 0.011 | 0.085* | 0.012 | 0.065* | 0.005 |
| | (0.016) | (0.009) | (0.023) | (0.012) | (0.021) | (13.115) | (0.014) | (0.021) | (0.010) | (0.023) | (0.012) |

Notes:

- All regressions control for age, income, online tenure, hours online, and education categories
- Omitted category is broadband in neither 2005 nor 2006
- Activities shown if the coefficient on adopted broadband is statistically significant in either time period
- Results for 2005-2006 are replicated from tables 10 and 11
- Other change-in-broadband categories included in the regressions but not shown

Table 14: Treatment Effect in Underserved Areas

| Dependent variable is change in: | Download music | Download music (weekly) | Visit local/city guides | Purchase online | Purchase online (dollars, last 3 months) | Visit adult entertainment sites | Research drug information (monthly) | Research medical conditions (monthly) |
|---|---|---|---|---|---|---|---|---|
| Coefficient on **adopted BB** over the period: | | | | | | | | |
| Everyone | 0.052*<br>(0.015) | 0.026*<br>(0.009) | 0.034<br>(0.020) | 0.053*<br>(0.020) | 33.938*<br>(12.909) | 0.026*<br>(0.012) | 0.030*<br>(0.009) | 0.032*<br>(0.011) |
| Low-density ZIP's | 0.152*<br>(0.029) | 0.048*<br>(0.017) | 0.096*<br>(0.040) | -0.013<br>(0.042) | 24.743<br>(23.644) | 0.044*<br>(0.022) | 0.027<br>(0.016) | 0.056*<br>(0.020) |
| Low-income ZIP's | 0.060<br>(0.033) | 0.022<br>(0.020) | -0.001<br>(0.045) | 0.061<br>(0.043) | 28.913<br>(21.815) | 0.059*<br>(0.025) | 0.034<br>(0.020) | 0.062*<br>(0.025) |

Notes:

- All regressions control for age, income, online tenure, hours online, and education categories
- Omitted category is broadband in neither 2005 nor 2006
- Activities shown if the coefficient on adopted broadband is statistically significant in either time period
- Results for everyone are replicated from tables 10 and 11
- Other change-in-broadband categories included in the regressions but not shown

Table 15: Displacement of At-Work Activities

| Dependent variable is change in: | Download music | Download music (weekly) | Purchase online | Purchase online (dollars, last 3 months) | Visit adult entertainment sites | Research drug information (monthly) | Research medical conditions (monthly) |
|---|---|---|---|---|---|---|---|
| Adopted BB | 0.037* | 0.014 | 0.059* | 35.142* | 0.026 | 0.031* | 0.035* |
| | (0.018) | (0.011) | (0.024) | (15.667) | (0.014) | (0.011) | (0.013) |
| Adopted BB * BB at work '05 | 0.081* | 0.047* | 0.032 | 18.201 | 0.026 | 0.008 | 0.020 |
| | (0.024) | (0.015) | (0.032) | (20.643) | (0.019) | (0.014) | (0.017) |
| N | 6056 | 6056 | 6056 | 6056 | 6056 | 6056 | 6056 |
| R-squared | 0.01 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.01 |
| Share doing | | | | | | | |

Notes:

- All regressions control for age, income, online tenure, hours online, and education categories
- Omitted category is broadband in neither 2005 nor 2006
- Activities shown if the coefficient on adopted broadband is statistically significant in either time period
- Other change-in-broadband categories included in the regressions but not shown

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